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Climate of the Past Discussions

Interactive comment on "The role of East-Tethys seaway closure in the middle Miocene climatic transition (ca. 14 Ma)" *by* N. Hamon et al.

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General comments

Hamon et al. perform four atmosphere-ocean general circulation model experiments aimed at addressing the long proposed hypothesis that the production of warm, saline intermediate water in the Miocene Tethys played a decisive role in global climate change. The subject of this study is welcome and fits well with the themes of Climates of the Past. The methodology is sound (pending some details – see below) and the manuscript is well structured. However, some refinements (some minor, some not) and extra discussion are required before the manuscript should be accepted.

The authors have identified a gap in the literature regarding the "Tethys Indian Saline

Water" (TISW) hypothesis, first proposed in the 80's, and have performed sensitivity model experiments to specifically test this hypothesis. However, the introduction doesn't review previous modelling work in any detail. While as far as I'm aware this is the first general circulation modelling study to specifically address TISW, several Miocene modelling experiments (many cited in the discussion) exist which should be introduced here. Additionally some extensive box modelling has been performed on the subject which needs to be integrated into the discussion [Karami et al., 2009; Karami et al., 2011]. The introduction should include what previous studies found regarding TISW, how they are lacking (or why those studies are inadequate for the problem at hand) and thus why this paper is being written. This point shouldn't be difficult to make, but still needs to be made. 'Major' revision is harsher than warranted but I believe this contribution could be made more substantial with consideration of the points outlined.

Specific comments (in no particular order)

-In the introduction and discussion the authors mention three mechanisms that have been proposed to explain Antarctic ice-sheet expansion via TISW. I) a decrease in Indian Ocean poleward heat transport due to east Tethys gateway closure, II) acceleration of the ACC and increased thermal isolation of Antarctica (though fixed-SST experiments show this has a relatively minor impact), and III) increased AMOC which would have led to increased moisture transport and precipitation to Antarctica. It should be noted to the reader that mechanism one and three are at odds with each other; one suggests increased heat transport to Antarctica is responsible for pre-MMCT warmth while three suggests increased heat transport leads to ice-sheet growth (similar opposing arguments exist for Greenland). On a related note, the model results here show that a deep eastern passage way leads to TISW, while a shallow/closed passage precludes this but leads to stronger outflow into the Atlantic and a strengthening of the MOC; this is an interesting result and it would be interesting to see plots (or at least numbers) of the changes in ocean heat transport, if they are significant. I suspect reduced heat transport toward Antarctica in the Indian Ocean under a closed gateway

scenario would be somewhat compensated for by increased transport in the Atlantic Ocean.

-No details are given of model equilibration. Has the AMOC finished trending? What of temperature and salt trends? Also, it's good that FOAM compares well with other general circulation models for modern climate, but what are its significant biases with regards to the aspects relevant to this study? (e.g. it's Miocene Drake Passage throughflow seems extremely weak compared to modern observations, what is modern transport like?). The reader needs to know broadly how well the model can capture modern and/or Miocene climate.

-Throughout the paper comparison is made to other Miocene studies that used slab ocean models. I think at this point it would be beneficial to only compare to coupled models (apples to apples), especially since some of the cited slab ocean studies didn't use heat fluxes derived from a coupled model in the first place. Similarly, on page 2120 line 9 the authors cite modelling studies that concluded CO2 must have been higher during the Miocene based on the fact that these models couldn't replicate proxy-derived temperatures. Here again some of these models only use a slab ocean with heat fluxes not derived from a coupled model.

-The authors have achieved an interesting result with their model (TISW formation) that other models have failed to achieve, as cited in their discussion. I know at least in my Miocene simulations TISW didn't form due in large part to the high river runoff to my Tethys. Thus this is an important and likely answer-changing boundary condition. The authors say river runoff was low, but what was the river transport in FOAM like and how was it prescribed?

-The Tethys gateway vs CO2 debate mentioned here is interesting and parallels that of the gateway vs CO2 hypotheses for the Eocene-Oligocene Transition. The authors should mention the fact that ice-sheet modelling has shown that increases in poleward ocean heat transport does little to affect Antarctic ice-sheet growth [DeConto and Pol-

lard, 2003] and fixed SST runs have already shown too that large increases in SST around Antarctica have little effect on the continental interior [e.g. Huber and Nof, 2006]. While this argument might be slightly different for the Miocene, given an ice-sheet was always present, it's an important point to note when discussing the MMCT. In this light, it's not surprising that even dramatic changes to gateways don't have a large impact on Antarctic climate in the model. The manuscript would benefit from a more explicit discussion of this; while it is oceanographically interesting determine whether and under what conditions TISW formed, a more important question is 'does/should it even matter for global Miocene climate?'. This paper clearly contributes to the answer but the setup for the question needs fleshing out. Such a discussion will give this paper the strength needed to help put the idea that TISW had a critical role in global climate to rest.

-When specific depths are mentioned in statements like page 2128 line 8, it should be noted to the reader that these are obviously model dependent.

-Page 2130 line 9 the authors suggest climate sensitivity was higher in the Miocene compared to present based on Miocene simulated sensitivity vs the IPCC sensitivity range. But to make this statement accurately the present day sensitivity would need to be compared to Miocene sensitivity using only the models adapted for the Miocene (i.e. that of Hamon et al. [2012] and Krapp and Jungclaus [2011]). What is FOAM's and ECHAM's modern climate sensitivity?

-Page 2130 line 16: This paragraph mentions the burial of carbon in the Paratethys. But nowhere in the manuscript is the Monterey hypothesis touched upon [Vincent and Berger, 1985] which would have also been a positive feedback on climate deterioration and one of the central competing hypotheses explaining Miocene cooling.

Technical/minor corrections

-Title: capitalise the Middle Miocene Climate Transition, since it is a name for an event.

-Page 2117 line 10: replace “development” with “expansion” since the EAIS was already present before the Miocene.

-Page 2117 line 12 needs a reference.

-Page 2118 line 13 change to “Moreover, inferences based on carbon and oxygen isotopes. . .”, since the proxies themselves don’t suggest heat transport changed.

-Page 2120 line 13 Herold et al. [2011] also showed this.

-Please check the order of citation of your figures (e.g. I think figure 10 is cited before figure 9).

-Make the plot line colours consistent between figures 9 and 10.

-Please ensure your maps have consistent aspect ratios and that they’re not distorted (e.g. Fig. 1 is ‘squashed’).

-Page 2123 line 3: Elaborate on this sentence.

-Figure 11a caption is backwards, should be “MioC – Mio4000”?

-Page 2123 line 26: at what depths have you considered “deep water”?

-Figure 8a. I assume Atlantic MOC is calculated over the entire east-west extent of the basin. What is that large anticlockwise cell at 4km depth at the equator? I don’t think this is realistic. Please check the treatment of the basin boundaries in your calculation.

-Page 2127 line 24: if both Flower and Kennett references suggest East-Tethys closure as a driver of the MMCT then only cite the earlier one. You can also add Ramsay et al. [1998] to this list.

-Page 2128 line 7: I don’ think anything can be “assumed” from the results, change this to “we suggest” or something similar. Same with line 23.

-Page 2129 line 1: change “amplified” to “added to”. Line 2: change “or” to “coupled with” or something similar.

-The manuscript should be read through for some minor English errors but these do not prevent the manuscript from being understood.

References

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Interactive comment on Clim. Past Discuss., 9, 2115, 2013.